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FINAL REPORT ON THE "Geography and evolution of sandspits and salt marshes on the north shore of Long Island and related areas."

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ABSTRACT

With the assistance of three senior students, the writer carried out a reconnaissance of every sand spit and enclosed salt marsh along the north shore of Long Island. Lloyd Point spits were mapped in detail. Before and since the contract period comparative visits have been made to similar spits situated at many points between Maine and Florida, as well as several areas overseas. Offshore dredging and SCUBA diving sampling was carried out, determining a shallow limit to longshore sand transport, the deeper areas being occupied only by organic muds and silt, an important engineering fact, in the event of artificial beach sand replenishment projects.

Study of the wind vectors for significant periods shows that beach-building storms occur from every quarter in Long Island Sound, yet the shore geomorphology on the north side differs markedly from that of the south shore. Examination of tidal records and geodetic relevelling data show that the whole area is subject to a slow crustal subsidence, and thus a rising of sea level. A world-wide check of sea-level change showed that a eustatic rise over the last half century had to be added to the local apparent rise, giving an effective rate of shoreline drowning over this period of about 2-3 mm/year. Surge, seiche, wind pile-up and steric effects tend to obscure

this figure on any annual curve. Local geomorphic history of northern Long Island is interpreted as due primarily to wave energy alternations expressed on a special lithologic type (Pleistocene till and outwash), while essentially identical energy, crustal and sea level conditions on the opposite side of the Sound are expressed on a coast of mainly hard crystalline rock.

Principal scientific discoveries directly aided by this research project include:

1. The recognition that the Appalachian-Adirondack axis is rising by 3-5 mm with respect to the coast at New York City.
2. The region of New York City and of Long Island Sound is undergoing crustal lowering in the present century at the rate of about 1.5 mm a year. These figures can be made more precise by future geodetic work.
3. There was a world-wide rise of sea-level in the first half of the present century averaging 1.2 mm a year. Patterns for any one year may not be distinguished because of local steric and storm effects. Future analysis of solar-climatic data may permit long-term prediction.
4. Coastal morphologic patterns are grossly dictated by relative crustal motion or sea-level change, so that coasts of emergence or submergence may be recognized as identified long ago by Douglas Johnson and earlier workers (Gulliver,

Davis), but not always with sound criteria: thus the north shore of Long Island Sound might be identified as a coast of youthful submergence (rias valleys) while the south shore would be one of emergence (straight or gently curved beaches), or possibly "early mature" submergence (if one considers a sector with headlands).

5. What process accounts for both shores? Evidently a) submergence (gross form); b) short-term oscillations of sea-level (the crust does oscillate in aseismic areas), cutting cliffs and building spits and marshes in areas of soft materials; but rias and skerries on hard-rock shores.

6. Microgeomorphic landforms (ripples, etc.) reform daily, middle-scale features (category "b" above) call for cycles of up to several centuries, while gross forms (category "a") require periods of the order of 1000 to 10,000 years to evolve. A simple formula, comparable to the Faegri Laws of climatology, has been worked out. Thus 1 mm of sea level change equals 1°C of mean annual world temperature x Time (years).

I. INTRODUCTION

The following description of a reconnaissance of the physical geography and evolution of sandspits and salt marshes on the South shore of Long Island Sound was undertaken with the assistance of an Office of Naval Research contract, Nonr 266(69) for twelve months beginning September 1, 1959.

Owing to industrial exploitation during the present century, spits and swamps of Long Island's north shore are being rapidly destroyed (by gravel dredgers). It seems to be of great value to take advantage of this area, which has long historical records and work out its geomorphic history before the natural picture has been effaced. It was observed that sands are also building out into the Sound at 2 to 10 fm. depth, and some offshore observations would be appropriate. We therefore hired a small boat and carried out dredging and SCUBA diving studies.

It was suspected that offshore (or beneath the present spits) there would be traces of lower spits and swamps formed during earlier stages of low sea-level, already determined in the Sound area by radio-carbon dating of a "drowned forest" at Pelham Bay (2700 years B.P.). Hand boring did not locate such peats, but deep boring for the Throg's Neck Gridge, disclosed two such horizons which were later radiocarbon dated (late Pleistocene/early Holocene transition, as expected).

During the preceding 12 months, the principal investigator had been making a preliminary study of Long Island spits and marshes. An historical sequence of four maps (1 inch equals 500 feet) illustrated the successive changes at a typical location, Lloyd Point, from 1685, copies of which have been submitted to ONR. (Fig. 4, 4a, 4b, 4c) This sequence was based on personal surveys, air photographs (back to 1930), U.S.G.S. charts (back to 1814) and early land surveys back to colonial days.

It has been determined that about 200,000 cubic feet (7600 cubic meters) of sand and gravel moved eastwards along the beach in the average year. Sections cut show that the salt swamps consist of alternately layered sand, gravel and peaty clay. The history of the swamps is now believed to reflect brief periods of inundation (gravel building), alternating with periods of peat building (drops of sea level).

In order to understand the regional setting of this sector of coast the geodetic pattern of crustal change, from the Canadian border to New York City, was worked out. Then the world pattern of sea-level change was established by re-examining the records begun by Gutenberg, Patullo and others, but <u>selectively</u> analysed, to avoid tectonic areas.

No comprehensive survey of all this work (within the limits of a single volume) is possible, because of its large scope. Numerous papers have been published or are still in preparation. These will be listed and summarized below. After the completiong of the 12-month project all the time and funds available had been exhausted. No further financial support was obtained, so that the studants working on the program were obliged to take positions elsewhere and the reports had to be written up slowly, from time to time, as opportunity presented itself; one student went to sea with R.V. Vema, and three had to go to other universities where funds were available for their maintenance. The principal investigator has carried on the research as far as possible with his private funds and several thousand dollars have been spent preparing and publishing these reports; almost all secretarial services, photography, drafting, and supplies have been provided by the principal investigator. During the course of the 12-month project period, these services were provided by the ONR contract. It is our pleasure to acknowledge the most helpful and understanding cooperation from Columbia University Government Contract personel and ONR representatives.

II. STUDENTS TRAINED

It is the policy of the principal investigator to give the training of students his highest priority. Without practical field problems, their training is liable to be academic and stultified.

The students so trained are as follows:

a) Oswald A. KREBS, Jr.; after completion of his M.A. at New York University he joined the staff of American Overseas Petroleum Co. (Caltex Group), later becoming senior geologist in Libya and now in charge of their North Sea off-shore drilling program.

b) Frederick F. WRIGHT; has continued his studies at Texas A & M and completed his Ph.D. at the University of Southern California under Professor D.S. Gorsline.

c) Walter S. NEWMAN; has studied micropaleontology at New York University and is currently Assistant Professor of Geology at Queens College of the City University of New York.

d) Charles C. WINDISCH; oceanographer, research assistant, Lamont Geological Observatory, Palisades, New York.

A post-doctoral visitor from the Sorbonne (University of Paris, France), Dr. W.D. Nesteroff, was with us for most of the period, and has since become Assistant Professor of Oceanography at the Sorbonne and is in charge of their new oceanographic research ship.

III. SUMMARY OF FIELD OPERATIONS

a) Shore Survey. This was carried out by automobile to nearest coastal points, and completed on foot. Air photographs were used for location. Levels were obtained by Abney, except where current measurements or more precise figures called for plane table and alidade.

b) Off-shore Survey. Small (25 foot) launches were rented in September 1959 and again in June and July 1960, on each occasion for a few days at a time, to take advantage of favorable weather and economize on expensive "ship-time." SCUBA diving was not practicable during stormy weather owing to excessive turbidity inhibiting visibility, and near-shore dredging operations were too dangerous with onshore winds. A special conical dredging instrument, designed by Dr. Nesteroff proved invaluable; it was effective 85 per cent of the time, where other standard devices had failed completely (owing to mixed rocky bottom, gravel and mud). We installed a small yacht-type, portable echo-sounder on our vessels and this was found to give excellent service to depths of over 100 feet, provided that the vessel speed was kept down to 10 knots or less; at high speed, ship noise (mainly bubbles) rendered it ineffectual. Thus on station it was satisfactory, but on long trips it could not be relied on for navigation, so that in rocky waters one may shut off the throttle from time to time for a reading.

IV. SUMMARY OF LABORATORY OPERATIONS

Beach sands were seived to obtain sorting characteristics, examined by binocular microscope for granular characteristics and approximate mineral counts; heavy liquids and the petrographic microscope were used for mineral identification.

Offshore deposits were mainly muds, but some coarse materials, sands, gravel and boulders (glacial, wave-winnowed residuals) were also collected. The muds and silts were generally treated with H_2O_2 to obtain the organic percentage and studied in detail for microfossils and mineral characteristics as described in detail by O.A. Krebs (see ~~summary below).~~ table: "Data chart of Sediments from Southern Long Island Sound").

U.S. Coast and Geodetic charts (over the last 130 year period) were obtained, and particularly useful were photostats of the original 1:10,000 survey sheets. Some remarkable changes in littoral patterns (spits, offshore depths) were observed.

The U.S.C.G.S. (Admiral Charles Pierce) was also most helpful in providing geodetic levelling data over two traverses of the northeastern Appalachian belt from New York City or vicinity. While warning us of the dangers of frost-heaving, compaction and human interference with levelling markers, we were able to eliminate obviously disturbed stations and obtained a reasonably systematic record.

The use of radioactive tracers was planned for studying spit evolution, but the A.E.C. was unable to assist us in time for this project. The equipment was delivered subsequently and we have been able to initiate some useful studies.

Records of world-wide tide records were obtained from the International Association of Physical Oceanography (Prof. Hakon Mosby) and the United States figures were supplied by the late Mr. L.P. Disney and Capt. K.G. Crosby of the U.S.C.G.S., who was exceptionally helpful in many ways.

V. SUMMARY OF LITERATURE RESEARCH AND MEETINGS ATTENDED.

Literature pertaining to the human history of the area, the techniques appropriate to our work and the regional and international research in this area was closely studied.

Several national and international meetings were attended (in part, at personal expense), including the International Union of Geodesy and Geophysics, Helsinki, July, 1960 (the writer attended the foundation meeting of the new Commission on Coastal Oceanography: chairman, Dr. V.P. Zenkovitch); the 19th International Geographical Congress, Stockholm, August 1960 (the writer attended the meeting of the International Commission on Coastal Geomorphology: Dr. A. Schou); the International Geological Congress, Copenhagen, August 1960 (member of International Stratigraphic Commission ; attended sedimentological field trip to coastal regions of Denmark under Dr. Kaj Hansen), all in summer 1960. In 1961 the writer visited Warsaw to attend the 6th International Association of Quaternary Research (INQUA); writer elected President of Shorelines Commission (re-elected in 1965 for the next four years).

In 1964 the principal investigator attended the Ninth Conference on Coastal Engineering (at Lisbon) and later the 20th International Geographical Congress (in London), where he served as chairman of the Section of Climatology, Oceanography and Hydrology. In 1965 he attended the 7th INQUA in Boulder, Colorado, serving as chairman of a session on Quaternary Shorelines and Marine Stratigraphy. Many local meetings have been attended and addressed; a particular effort has been made to help raise the appreciation of archeologists to the significance and usefulness of sea-level and climatic changes over the historical and late pre-historic period. Fruits of this effort are now to be seen in many reports of archeologists who are tracing littoral sites above and below sea level approximately as predicted.

VI <u>SUMMARY OF PUBLICATIONS AND PUBLIC PRESENTATIONS</u>

No. 1 1960. "The changing level of the sea." Sci. Amer., vol. 202, pp. 70-79 (Freeman Reprint no. 805).
(Note: This is a semi-popular statement of the problem of shoreline change. Several thousands of copies are distributed annually by Freeman Reprints to schools and colleges.)

No. 2 1960. "Recent world-wide sea level changes." <u>Bull. Mass. Archaeological Soc.</u>, vol. 21, pp. 49-51.
(Note: This is an extract of the eustatic-climate theory applied to the needs of archeologists working around Long Island Sound and New England. Archeologists report that the climatic correlations have been useful in explaining paleo-Indian habitats and migrations. Louis Brennan obtained a C^{14} date for the Croton Point oyster midden that correlates precisely as predicted; the largest sized oyster individuals correlate with the warmest predicted phase of the Holocene.)

No. 3 1960. "Long-range correlation of Solar Radiation, Climate and Sea-Level Cycles." Trans. <u>Amer. Geophys. Union</u>, Abstracts 41st meeting.
(An illustrated summary of this article is submitted as an appendix.)

No. 4 1960. "Eustatic changes in sea-level." <u>Physics & Chemistry of the Earth</u>, vol. 4 (London, Pergamon Press), pp. 99-185.
(Note: This is a comprehensive summary of the entire eustatic problem, published in a fundamental series on <u>Physics and Chemistry of the Earth</u>; it introduces the most modern assemblage of C^{14} dates and also outlines the question of <u>geodetic changes of sea level</u>, which is a new concept in Science.

No. 5 1960. "World Sea-level and Climatic Changes." <u>Wenner-Gren Foundation for Anthropological Research</u>. Burg Wartenstein Symposium, 44 pp. <u>Reprinted</u> as "World sea level and climatic changes." Quaternaria, Rome, vol. 6., 1962.
(Note: This was presented in a ten-day conference of archeologists concerned with the dating of habitats and migrations of ancient man in the Mediterranean region and North Africa. It contains the first attempt at mathematical formulation of the eustatic principle.)

No. 6 1960. "Oscillations of mean sea-level and post-glacial uplift in Finland." Int. Assoc. Physical Oceanography (I.U.G.G., Helsinki, 1960), Abstracts.
(Note: This was presented in Helsinki, and contained a curve specially adapted to show the uplift of Helsinki, and Scandinavia generally, interpreted in terms of eustasy. The Finnish geologist Hyppaa confirmed that "hinge reversals" are ruled out and the eustatic curve now provides a basis for determining the even rate of crustal upwarp.)

No. 7 1960. "Spit and marsh building on north shore of Long Island Sound, New York." Commission on Coastal Sedimentation (Int. Geographical Union, Stockholm, 1960). Abstracts.
Abstract as follows:

The Long Island north shore consists largely of late Quaternary glacial outwash gravels and sands, resting on the Harbor Hill till (boulder clay), which was left behind by the last glacial (Wisconsin) retreat. Deeply dissected, with hilly topography, exceeding 50 m relief, it displays a deeply indented coastline, typically "drowned" by the post-glacial eustatic rise. Headlands are truncated by actively eroding cliffs and the debris is building out to form spits parallel to the coast, in many cases sealing off the bays in the manner of bay-mouth bars. Principal examples studied are: Prospect Point, Oak Neck, Lloyd Point, Lloyd Neck, Eaton Neck, Sunken Meadow, Nissequogue Neck, Stony Brook Harbor, Crane Neck, Port Jefferson, Mt. Sinai.

Lloyd Point spit, a typical case, was studied also by means of early charts (since 1685) and air photographs (at short intervals from 1930 to 1958). It shows a progressive building to the west from isolated cliffs on the east side, involving an annual sand and gravel movement of 7000 cubic m (200,000 cubic feet). Sand and gravel encroach progressively on to the black organic mud (gyttja) of the bay floor. Coarsest boulders rest at the foot of the out-building spit; thus the sedimentary gradation from the shore is in the following orders: medium-grained sand (beach), coarse sand and gravel (spit slope), coarse boulders (spit foot), fine-grained black mud (bay floor). Evidently maximum transport is by wave action along the beach impelled by the Atlantic swell from the east. Local winds and current directions are anomalous; they are dominantly from the west.

Offshore bars are located in shallow platform areas at depths of about 3 m below LWM. They are characterized by fine-grained sands and coarser components, and may be relics of normal shore spits formed during periods of lower sea-level, still stands or oscillations associated with the post-glacial eustatic rise. A "drowned forest" marking one such low stand near New York City (Throg's Neck, Pelham Bay) was C^{14} dated by Libby (C-943) at 2830 years B.P.

To the interior of the spits are intertidal salt marshes rising to the limit of high tide, with layers of peat resting on older gravels; these are being largely removed today by gravel dredgers for building materials.

No. 8 1960. "Glacial Lakes in Long Island Sound," (with Walter S. Newman). Bull. Geol. Soc. Amer., vol. 71, pt. 12, (Abstracts). Abstract as follows:

The Southern New England sounds are marked by three bathymetric basins which were occupied by fresh-water lakes in the Late Wisconsin. At their greatest extent, these lakes were contemporaneous and continuous with other lakes in the area now occupied by metropolitan New York and covered an area of about 4000 square miles. These lakes (earlier suspected by Hollick, Antevs, and Lougee), traced through Long Island, Block Island, and Rhode Island sounds, were formed in a Tertiary subsequent valley, flanked on the south by the Cretaceous of the Long Island-Martha's Vineyard cuesta. With the initial retreat of the ice about 30,000 years B.P., the basins were dammed by the Long Island terminal moraines.

Distortion and over-consolidation of some varved lacustrine sediments indicate the presence of post-Ronkonkoma proglacial lakes, whereas the greatest development of the lakes in the area was post-Harbor Hill, dating about 24,000 years B.P. We propose to call this stage "Glacial Lake Antevs." The lake sequence was terminated by isostatic rebound and the apparent catastrophic breaching of the morainal dam east of Long Island which aided the erosion of Block Island Submarine Canyon.

The warping of the Sangamon (?) Pamlico-Cap May-Gardiners datum from south to north across New Jersey suggests a former marginal bulge, which may be isostatically subsiding, as shown by the anomalous negative behavior of the City of New York tide gauge.

No. 9 1960. "Active subsidence in the New York area," (with Walter S. Newman). Bull. Geol. Soc. Amer., vol. 71, pt. 12, (Abstract). Abstract as follows:

The tide-gauge record at New York City shows an apparent rise of sea level of 165 mm between 1900 and 1950. Analyses of world-wide tide records, selected to eliminate the

tectonically more active regions and obviously unreliable stations, show a secular rise during that period of about 60 mm, which is interpreted as eustatic. The residual anomaly of 105 mm, or approximately 2 mm per year, is attributed to contemporary subsidence. All eastern North American gauges show similar anomalies. The Atlantic Coastal Plain geosyncline, south of New York, readily explains this phenomenon; the subsidence north of this hinge may call for post-glacial crustal adjustment.

Marine sediments of Sangamon interglacial age (Pamlice/Cape May) occur from New Jersey south to Florida, at up to 25 feet above sea level. Northeast of New York, however, Sangamon equivalents (Gardiners clay, etc.) are rarely found undisturbed higher than 50 feet below sea level and drop to -100 feet in southern Long Island. Paleoecologically these formations, according to Richards, are all warm interglacials. If the age is approximately 100,000 years and the minimum tilt from New Jersey to Long Island is 25 m, then the maximum subsidence should be only 0.25 mm per year near New York city. It seems more likely that the secular subsidence is a purely post-glacial phenomenon, not older than about 15,000 years. The drowning of Long Island Sound and depressions to the northeast support this suggestion.

This subsidence is just the opposite in sign to a simple post-glacial isostatic rebound. It seems to be the peripheral bulge of Daly (and others) and may indeed by part of a highly viscous crustal ripple that migrated out from the retreating ice front.

No. 10 1961. "Radiation Solaire et variations cyclique du niveau de la mer." Rév. Géogr. Phys. et Géol. Dyn. (Paris), ser. 2, vol. 4, pp. 2-14.
(Note: A summary in French of the Lyellian proof of glacio-eustasy.)

No. 11 1962. "Sea level and the Southern Oscillation." (with Oswald B. Krebs, Jr.) Geophysical Journal, London, vol. 6, pp. 532-545.
Summary as follows:

An average curve for the world annual mean sea level for the century 1860-1960 has been obtained from a carefully selected world series of tide gauge records. We have eliminated data from tectonically unstable areas and other obviously anomalous records. Five-year running means provide us with a residual curve that may approach a eustatic standard (probably glacio-eustatic). The lowest point of sea level was about 1890; the mean rise from 1900-1950 was 1.2 mm annually, but the fastest decade was 1946-1956 with 5.5 mm. The pattern varies somewhat if plotted ocean by ocean.

The non-smoothed, annual curve shows a 2-3 year cyclicity of 10-30 mm amplitude. For the world curve this periodicity resembles the 2-3 year atmospheric pressure cycle known as the "Southern Oscillation," being in phase with the S.E. Pacific node. The reciprocal, Indian Ocean node is well reflected in the Indian Ocean, and periodically, dominates over the Pacific pattern in the Atlantic Ocean.

When the effect of a pressure anomaly of 1 mb is taken as equivalent to 10 mm departure of sea level, it is found that that is still a large residual generally in the same phase. It would seem that steric effects and associated wind systems are mainly responsible.

No. 12 1961. "Convergence of Evidence on Climatic Change and Ice Ages." N.Y. Acad. Sci., Annals, vol. 95, no. 1, pp. 542-579. (Note: See Abstract in Appendix 2.)

No. 13 1961. "La base eustatique de la geomorphologie." Ann. Geographie, vol. 70, pp. 488-492. (Note: French summary of Int. Geogr. Congress presentation.)

No. 14 1961. "Postglacial crustal subsidence of coastal New England," (with Walter S. Newman), Geol. Soc. Am., sp. pap. 68, pp. 239-240. Abstract.)
Abstract as follows:

Data indicate that coastal New England has been subsiding since the mid-Holocene. Tide-gauge records for the interval 1900-1950 suggest an absolute crustal subsidence of 1.0-2.0 mm/year after eustatic and steric corrections. Coast and Geodetic Survey first-order levelings between Rouses Point on the Canadian border and Perth Amboy, New Jersey, indicate that the New York metropolitan area is subsiding at a rate of 1.4-2.7 mm/year relative to Rouses Point. Eustatically corrected data from radiocarbon-dated drowned archeological sites and drowned forests and peat bogs confirm that crustal subsidence has been continuous in southern New England at a rate of 0.8-1.6 mm/year for the past 7000 years. Raised marine sediments north of Cape Cod indicate postglacial crustal rebound prior to 6000 years B.P., whereas departures from the Fairbridge (1961) eustatic curve suggest that crustal rebound has occurred in the Long Island area sometime prior to 7000 years B.P.

The 20 m difference in the elevation of the top of the Pamlico Gardiners (Eem) Formation in southern New Jersey and on Long Island indicates post-Sangamon crustal subsidence of Long Island which may have been induced by Wisconsin glaciation. Differential subsidence of the northeast coast of North America is thus complex in origin and probably also reflects subsidence of the Atlantic Coastal Plain geosyncline. Similar postglacial warping of the Eem Formation in the Netherlands indicates a like mechanism, thus evidently supporting the hypotheses of Daly and Vening Meinesz of postglacial peripheral subsidence bordering recently deglaciated and rising areas.

No. 15 "Mean sea level related to solar radiation during the last 20,000 years." In: Changes of Climate, UNESCO-WMO Symposium, Rome, 1961, pp. 229-242.
(Note: Summary of glacio-eustatic principle for international group of meteorologists.)

No. 16 1962. "Postglacial sea level, coastal subsidence and littoral environments in the metropolitan New York City area," (with Walter S. Newman). Coastal and Shallow Water Res. Cong. 1962, pp. 188-190.
(Note: See Appendix 3.)

No. 17 1965. "Sea-level and the Holocene boundary in the eastern U.S." INQUA, VIth Congr., Poland, vol. 1, pp. 397-418 (with Walter S. Newman).
Abstract as follows:

A "standard" eustatic curve for the past 20,000 years has been presented (1960, 1961) using over 100 radiocarbon-dated samples of littoral fossils from all parts of the world. About 11,000 years B.P. represents the major break from cold to warm in deep-sea faunas. The Allerød (Two Creeks) sea level at that stage was about -30 m and was separated from the renewed melting trend by the Salpausselkä (Valders) regression to about -35 or -40 m ending at approximately 10,500 years B.P. Considering the retardation of eustatic rise with respect to air temperatures, it is obvious that the world temperature has warmed up before sea level reached its present mean, about 6000 B.P. Since 11,000-10,500 years B.P. represents an important world-wide marine break, it is stratigraphically the most desirable lower boundary for the Holocene. Climatologically it is also consistent with a post-glacial epoch.

The Wisconsin chronology of the eastern United States is still poorly known. At its maximum extent, glaciation extended south to latitude 40°35' N forming the outermost Long Island morainal complex sometime prior to 15,000 B.P. Subsequent retreatal pauses are only locally discernable although evidence of the Two Creeks and the subsequent Valders readvance are present in Maine, the Champlain basin and in the upper St. Lawrence valley. Sediments of the so-called "Champlain" marine transgression are found in the St. Lawrence lowlands, the

Champlain valley, and in Maine and New Hampshire on the Atlantic coast with the maximum transgression occurring between 10,000 and 12,000 years B.P. Late Wisconsin marine sediments are not exposed south of the latitude of Boston.

Holocene crustal movements are discernable along the northeastern seaboard of the United States: they are not seen south of Chesapeake Bay. The coastal belt is divided into a geosyncline (south of Long Island), which may be very slowly subsiding, in places at least, and a crystalline coast from New York to Maine, where only off-shore islands (Long Island, Martha's Vineyard, Nantucket, etc.) have a sedimentary veneer. This northern sector coincides with the extent of Wisconsin ice cover. Crustal warping is indicated by the depression of Pamlico (Monastir) shorelines to -20 m below Long Island, and by positive tide gauge records in Maine and New Brunswick.

Contemporary climate changes (change in velocity of the Gulf Stream, etc.) may partly explain the remarkable tide gauge anomalies from Miami to Boston which suggest either abnormal coastal subsidence or sea level rise or both. Two C^{14} dates for submerged basal estuarine peats just northeast of New York City, give 6600±700 years B.P. for -15 m and 11,950 ±200 years B.P. for -33 m: the former is 5-10 m below the "standard" eustatic curve (still only an approximation!) while the latter, is close to it. This could be explained by a reversal from postglacial crustal rebound to marginal downwarp.

No. 18 1965. "Ancient shorelines and absolute dating." <u>INQUA VIth Congr.</u>, Poland, vol. I, pp. 653-676.

Abstract as follows:

A detailed examination of the multiple theories of shoreline displacement was recently made (Fairbridge 1961), since a clear recognition of the possible regional and local departures is essential to an accurate appraisal of the eustatic factor. It was concluded that most of the hypotheses, hopefully proposed as total solutions are, in fact, based upon real, natural processes, but only represent components in a complex multiple oscillation of ocean and land levels.

Long-term godetic changes (rotational velocity, polar migration, etc.) are not considered to be very significant over the ranges involved in the Quaternary. Of the various eustatic causes, the three principal classes differ in orders of magnitude-glacio-eustasy averages 1 mm yr^{-1}, tectono-eustasy 0.1 mm yr^{-1} and sedimento-eustasy 0.01 mm yr^{-1}. Local crustal departures will obscure or reverse such world-wide phenomena, the most important being:

(a) mainly positive movement (tectonic)--postglacial isostatic readjustment to crustal ice loading, locally oscillatory; geanticlines, tendency for orogenic belts to rise epiorgenically, locally reversed (block faulting, etc.);

(b) mainly negative movement (tectonic and atectonic) -- gravitational compaction of freshly-laid sediments (especially in deltas, with low density sediments, notably peats); secular subsidence in younger geosynclines.

Studies of tide gauge recordd have been made by Thorarinsson, Gutenberg, Cailleux, Valentin, and the writer in order to determine present relations of glacio-eustasy. From a mean 1.2 mm yr^{-1} from 1900-1950, local departures disclose mainly active geosynclines and geanticlines, apart from well-recognized glacio-isostatic regions. Other departures include anomalous trends in regional atmospheric pressure, winds, currents and related steric features (changes of water volume due to thermal expansion and contraction, etc.).

Absolute (isotopic dating of former shorelines is applied with two objects: a) determination of a standard glacio-eustatic record, providing geophysical data on absolute rates of melting, cyclicity and general quantification of climate changes, etc.; and b) determination, from the departures from the "standard norms," of the rates of local isostasy, tectonism, etc. Present limitations of absolute dating in the Quaternary are about 70,000 years from radiocarbon (C^{14}) analysis of $CaCO_3$ shells and wood or peat; preliminary results of ionium (uranium "daughter") methods indicate about 250,000 years.

No. 19 1965. "Coastal processes." In: <u>Oceanography for Space</u> (Woods Hole Oceanogr. Inst.), pp. 433-434.
(Note: This was an appeal with the varied groups of geographers, geologists, and engineers to <u>jointly</u> consider long-term investigation of coastal features by means of high altitude sensore: aircraft or satellite carried, and using varied devices such as stereo-photography, infra-red photography, radar scanning, etc.)

No. 20 1965. "Quasicratonic basin collapse during the Quaternary." <u>INQUA</u>, VIIth Congr., Denver, U.S.A., Abstract p. 137.
Abstract as follows:

Approximately 24 major oceanic marginal basins were formed or appreciably enlarged during the last two million years. These include those of the Bering Sea, Sea of Okhotsk, Japan, East China, South China and Philippine Seas, several Indonesian basins, Coral Sea, Tasman and the Melanesian basins, parts of the Mediterranean, Black Sea, Caribbean and Scotia Sea. Eustatic data suggest a net rate of crustal collapse that resulted in a secular (nonglacial) drop of world sea level of about 0.05 to 0.1 mm $yr.^{-1}$. Since the area of the oceans is $360x10^6 km^2$, the volume of crustal opening involved would amount to $36 \times 10^6 km^3$, in general terms a drop of the basin floors by 1,800 m over about 2 million km^2. Discontinuous collapse of many of these basins appear to have been going on since Cretaceous times. Emiliani has demonstrated at least 40° slopes at the crustal boundary planes.

Several models have been offered to explain this record. Mantle expansion, mantle convection, geodetic adjustments following polar shift, continental drift, etc., have been considered. Beloussov speaks of "basification" of the quasicratonic crust, but the mechanism is as yet unknown.

Whatever the cau e, the collapse of numerous marginal oceanic basins during the Quaternary must have appreciably modified oceanographic and atmospheric curculations. Precise measurement is recommended of the rates and times of the collapse phases by the seismic exploration and drilling of test bores on shelf-type (nonvolcanic) atolls in the Coral Sea, in the South China Sea, in the Maldives and in British Honduras. The best bore sites would be land-based and need not exceed 3,000-10,000 feet in most cases.

No. 21 1961. Oswald A. Krebs, Jr., "The Sediments of the South Shore of Long Island Sound--Lloud Point to Crane Neck Point." M.S. Thesis, New York University.
Abstract as follows:

Mechanical analyses of 133 samples and organic analyses of 99 samples from Long Island Sound, coupled with an evaluation of the existing tidal current data, indicate that material smaller than sand size is concentrated and deposited in areas of longest slack tide, areas in which the tidal currents are strongly rotational in nature, and in restricted basins where the "settling lag" and "scour lag" effects are pronounced. It is believed that these sediments combine with disseminated organic material to form an organic "sludge" prior to deposition.

Correlations between Eh, organic content, and sediment size indicate a basic interrelationship in which the Eh becomes more positive and the organic content decreases as the sediment size increases. The potassium dichromate method of organic analysis is outlined and a conical bottom sampler designed by Wladimir Nesteroff is described.

No. 22 1965. Walter S. Newman, "Late and Post-glacial Paleoenvironments of Long Island Sound." Ph. D. Thesis, New York University.

No. 23 1964. "Beach erosion and sea level changes, eustatic and other." IXth Conf. Coastal Engineering (Lisbon), no. 2-4. Note: See Appendix 4).

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DATA CHART OF SEDIMENTS FROM LONG ISLAND SOUND

sample number	ONR map number	DATE	TIME	Location	depth m/w in ft.	Temp degrees C	pH	Eh in mv.	Field Observation
14-1	8	6-14-60	12:15PM	40 55'40"N 73 30'40"W	33'	17.0	6.85	-265	Black mud - silty - rich in organic
14-2	9	6-14-60	12:30	40 55'35"N 73 30'20"W	45'	16.5	7.10	-354	Grey-black silty mud. High organic with strong H2S
14-3	10	6-14-60	12:45	40 55'30"N 73 28'02"W	22'	18.0	6.80	-100	Grey-brown sand with a few pebbles; some bioclastic
14-4	11	6-14-60	13:00	40 55'28"N 73 29'55"W	9'	17.5	6.90	+50	Grey-brown sand 5% bioclastic
14-5	14	6-14-60	13:20	40 56'45"N 73 30'02"W	50'	17.0	6.90	-175	Black silty mud 3% bioclastic
14-6	15	6-14-60	13:40	40 56'37"N 73 29'45"W	41'	16.5	7.45	-260	Grey-black clay Silty
14-7	16	6-14-60	14:00	40 56'44"N 73 29'25"W	16'	17.8	not avail.	+15	Coarse quartz sand - some pebbles
14-8	19	6-14-60	14:40	40 57'48"N 73 29'20"W	58'	16.0	not avail.	+50	Clean - well-sorted sand (whole shells)
14-9	18	6-14-60	14:55	40 58'12"N 73 29'12"W	58'	17.0	7.50	-170	Silty sand
14-10	17	6-14-60	15:05	40 58'27"N 73 29'30"W	71'	17.0	6.90	-175	Dark grey silty clay
14-11	20	6-14-60	15:15	40 57'37"N 73 29'15"W	30'	17.0	not taken	not taken	Clean coarse sand - with large shell fragments
14-12	21	6-14-60	15:25	40 57'23"N 73 29'13"W	23'	not taken	not taken	not taken	Coarse sand with 40% bioclastic
14-13	22	6-14-60	15:45	40 57'23"N 73 29'13"W	42'	17.0	7.35	-320	Grey silty clay
14-14	25	6-14-60	16:05	40 56'48"N 73 26'30"W	37'	16.5	7.20	-380	Grey-black silty clay - H2S
14-15	29	6-14-60	16:20	40 56'24"N 73 25'26"W	30'	17.5	7.50	-410	Grey silty clay
14-16	43	6-14-60	16:30	40 56'10"N 73 24'37"W	30'	16.5	7.20	-420	Grey silty clay
14-17	28	6-14-60	16:45	40 56'21"N 73 26'02"W	31'	17.0	7.30	-420	Dark grey silty clay with H2S
14-18	30	6-14-60	16:55	40 56'04"N 73 25'44"W	29'	17.0	7.20	-345	Dark grey silty clay with H2S
14-19	36	6-14-60	17:35	40 54'58"N 73 23'32"W	35'	18.0	7.10	-450	Dark grey clayey silt with strong H2S

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DATA CHART OF SEDIMENTS FROM SOUTHERN LONG ISLAND SOUND MICROSCOPIC ANALYSIS

Sample Number	Estimated %clay	%silt	%sand	%coarse sand& pebbles	%bioclastic	Remarks	%organic content
14-1	75	20	5		some	few forams, abundant faecal pellets some pyrite and mollusc shells fragments	4.74
14-2	90	9	+or- 1 (fine)			numerous faecal pellets, some small mollusc shells, forams & diatoms	5.76
14-3	5		90		5	Quartz grains, subangular to subrounded, generally frosted, some feldspar grains; occasional large foram. many grains show organic coating	0.24
14-4	so me		95		5	Mostly quartz, subrounded to rounded; occasional feldspar grain; some very large forams; limited dark minerals	0.27
14-5	25	25	50		some	Quartz grains, subangular to subrounded; abundant faecal pellets; occasional forams & diatoms; polychaete worms present;2 different species	1.80
14-6	40	30	30			Numerous faecal pellets and forams; less frequent diatoms	2.07
14-7	2		85	10	3	Quartz grains, subangular to highly rounded (coarser fraction), few forams & diatom tests; occasional large shell fragment	0.17
14-8	1		95	4		Mostly quartz with some feldspar and rock fragments; generally sub-angular to subrounded; occasional dark mineral	0.23
14-9	35	20	45			Occasional shell fragments and large micaceous grains; numerous faecal pellets; some forams & diatoms	1.17
14-10	50	30	20			Numerous faecal pellets; sand grains angular; micaceous silt material abundant; few diatoms and forams	2.03
14-11			100			Quartz sand; med.-coarse, subangular to subrounded (larger grains); some feldspar & dark minerals; low organic frosting varies; brown coating on some grains (organic or ferruginous)	0.12
14-12		5	40	15	40	Quartz sand, fine to medium, subangular to rounded frosting varies; large bioclastic fraction; brown to black organic grain coating	0.30
14-13	60	25	15 (fine)			Sandy clay, minor bioclastic, numerous faecal pellets; occasional forams; sand= clear quartz, subrounded to rounded with minor frosting	3.09
14-14	80	20				Grey-black clay; some silt; many faecal pellets; numerous diatoms & forams; polychaete worms present; occasional shell fraagment; silt fractions highly micaceous	5.62
14-15	80	20				Grey silty clay, minor sand fraction, frequent forams & diatoms; minor bioclastic with shell fragments; numerous faecal pellets	4.77
14-16	80	15	5 (very fine)			Grey silty clay, noticeable fine sand fraction; frequent forams & diatoms; minor bioclastic	4.07
14-17	90	10				Dark grey silty clay, abundant forams, diatoms & faecal pellets; occasional shell fragments and sand grains	5.51
14-18	95	5				Dark grey clay, minor silt, numerous faecal pellets, forams, diatoms	5.44
14-19	90	10			some	Dark grey clay, some silt; some shell fragments; silt grains subangular, some coated; faecal pellets abundant; forams & diatoms present; black (coated)? grains quite abundant	4.36

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DATA CHART OF SEDIMENTS FROM LONG ISLAND SOUND

sample number	ONR map number	DATE	TIME	Location	depth m/w in ft.	Temp degrees C	pH	Eh in mv.	Field Observation
16-1	85	6-16-60	13:35	40 58'57"N 73 02'08"W	61	18.0	6.75	-220	Green-grey clay, 1% bioclastic slight silt noted
16-2	86	6-16-60	13:47	40 58'33"N 73 02'21"W	37	17.0	6.50	+20	Poorly sorted sand - some bioclastic-very coarse to very fine
16-3	87	6-16-60	13:54	40 58'14"N 73 02'28"W	18	17.0	6.05	+130	Very coarse sand - pooly sorted-some bioclastic
16-4	88	6-16-60	14:00	40 57'59"N 73 02'36"W	9	not taken	not taken	not taken	Sand and gravel
16-5	82	6-16-60	14:17	40 59'13"N 73 03'56"W	69	15.0	6.50	-90	Grey silty clay
16-6	83	6-16-60	14:26	40 59'06"N 73 03'58"W	46	18.0	6.65	+10	50%bioclastic, 50% sand - poorly sorted-with some coarse sand
16-7	84	6-16-60	14:35	40 58'27"N 73 04'02"W	16	16.0	6.10	+120	Well-sorted med. grained quartz sand-little bioclastics
16-8	80	6-16-60	14:45	40 59'25"N 73 04'53"W	76	15.0	7.00	-120	Clayey sand
16-9	78	6-16-60	14:54	40 59'55"N 73 04'54"W	84	16.5	6.90	-60	Grey silty mud
16-10	76	6-16-60	15:05	40 59'10"N 73 06'26"W	65	14.5	6.60	+100	Poorly sorted sand - some clay
16-11	75	6-16-60	15:17	40 58'58"N 73 06'35"W	28	not taken	not taken	not taken	Hard substrata, probably rock, plus well-sorted sand and gravel
16-12	70	6-16-60	16:10	40 56'06"N 73 13'06"W	49	15.0	6.80	+30	Grey silty clay
16-13	71	6-16-60	16:25	40 55'04"N 73 13'24"W	39	16.0	6.70	-240	Sandy mud some bioclastic
16-14	72	6-16-60	16:34	40 55'00"N 73 13'36"W	5	16.5	6.40	+10	Poorly sorted sand medium - fine
16-15	74	6-16-60	16:55	40 55'42"N 73 12'15"W	35	16.0	6.50	-80	Medium sandy clay - silt
16-16	73	6-16-60	17:10	40 55'59"N 73 12'16"W	48	16.5	6.50	-200	Clay - some bioclastic, some sand, silt - grey
16-17	69	6-16-60	17:30	40 56'01"N 73 15'48"W	28	15.5	6.35	-90	5% bioclastic in poorly sorted med. sand-some clay, H2S odor
16-18	68	6-16-60	18:25	40 57'20"N 73 15'59"W	57	15.5	7.15	-190	Grey silty clay, some shell fragments
16-19	63	6-16-60	18:35	40 57'38"N 73 22'15"W	33	15.0	7.00	-140	Poorly sorted sand-very coarse to fine - 5% bioclastic

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DATA CHART OF SEDIMENTS FROM SOUTHERN LONG ISLAND SOUND

MICROSCOPIC ANALYSIS

Sample Number	Estimated %clay	%silt	%sand	%Coarse sand & pebbles	%bioclastic	Remarks	%organic content
16-1	90	9	some		some	Grey clay with silt and fine sand; faecal pellets abundant	4.70
16-2	10		90			Medium quartz sand, subangular to subrounded, moderate sorting, variable frosting and sphericity	0.15
16-3			85	15		Coarse sand with pebbles, subangular to subrounded sands, highly rounded pebbles; minor bioclastic	0.38
16-4			100			Sand and gravel	
16-5	70	20	10 (fine)			Grey silty clay; some fine sand, subangular to rounded, dark organic coatings on sands; numerous faecal pellets;forams & diatoms	2.31
16-6	5		15		80	Bioclastic with poorly sorted med. sand, shell fragments 0.0-20 mm and well reworked; sands are subangular to subrounded with brown or green organic coatings	0.41
16-7			100			Medium - coarse sand, some pebbles, grains subangular to subrounded; frosting varies; clear qtz. with some staining (Fe), some rock grains and bioclastic, relatively well sorted	0.15
16-8	10	20	70			Medium to fine sand rich in clay; sands subangular & moderately well sorted,some green coating(organic?),some faecal pellets,diatoms&forams	0.72
16-9	90	10				Grey silty clay;1 pink polychaete worm;faecal pellets abundant;forams & diatoms present; some small mica flakes; silt is clear qtz.- grains; occasional shell fragments	3.71
16-10		25	50	25		Poorly sorted sand trending to med;angular to subangular;mostly clear qtz. with some brown stain (algal?), some rock fragments; 1 white worm; some shell fragments and clay	0.27
16-11			100				
16-12	95	5				Grey clay, some silt, few small mica flakes;very abundant faecal pellets; occasional shell fragments; diatoms and forams present	4.77
16-13	40	45	15			Clay, rich in fine sand & silt; abundant faecal pellets; forams & diatoms present	0.94
16-14			100			Poorly sorted sand; mostly med-coarse grained;clear qtz, some rock fragments; 2 yellow worms; forams present; grains subangular to subrounded; varied frosting	0.24
16-15	40	35	25			Clay with sand and silt in fairly equal %; sand is quartzitic; numerous faecal pellets; some forams and diatoms	1.22
16-16	90	10				Grey silty clay; silt predominately clear qtz.,subangular; abundant faecal pellets & forams;diatoms present;occasional shell fragments	3.60
16-17			95		5	Poorly sorted med. sand, quartzose;grains generally subangular to subrounded-rounded; several types forams present; some polychaete worms; occasional rock fragments	2.79
16-18	85	15				Grey silty clay;clear qtz.; some mica flakes; shells & shell fragments numerous; forams numerous, diatoms present; faecal pellets very abundant: black-coated grains abundant	3.82
16-19			80	15	5	Poorly sorted sand trending to med. grain size; much bioclastic; some pebbles; clear qtz. grains, some coated, subangular-subrounded; some clay; some rock & forams	

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DATA CHART OF SEDIMENTS FROM LONG ISLAND SOUND

sample number	ONR map number	DATE	TIME	Location	depth m/w in ft.	Temp degrees C	pH	Eh in mv.	Field Observation
17-1	79	6-17-60	10:38	40 56'04"N 73 20'24"W	9	16.0	not taken	+30	Poorly sorted clean sand-med. to coarse-some bioclastic
17-2	67	6-17-90	10:55	40 56'40"N 73 20'04"W	49	16.0	6.70	-300	Grey silty clay with some fine sand
17-3	66	6-17-90	11:09	40 57'02"N 73 20'08"W	54	16.0	6.80	-330	Gelatinous grey clay with 71% clastic material-strong H2S
17-4	62	6-17-90	11:40	40 59'50"N 73 23'44"W	24	not taken	not taken	not taken	Poorly sorted sand coarse to very fine, some shell fragments
17-5	60	6-17-90	11:52	40 00'11"N 73 23'46"W	180	16.0	7.00	-190	Poorly sorted sand, clayey, coarse to fine 1% bioclastic
17-6	61	6-17-90	12:05	40 00'05"N 73 23'02"W	80	16.0	7.20	+10	Grey silty clay-some coarse to fine poorly sorted sand-pebbles some bioclastic and large shells
17-7	54	6-17-90	12:38	40 59'23"N 73 25'39"W	108	14.5	6.90	-290	Grey-black clay, slight sand & silt-minor bioclastic

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DATA CHART OF SEDIMENTS FROM SOUTHERN LONG ISLAND SOUND

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MICROSCOPIC ANALYSIS

Sample Number	Estimated %clay	%silt	%sand	%coarse sand &pebbles	%bioclastic	Remarks	%organic content
17-1			95	5	some	Med-coarse sand-mostly clear qtz., some rock grains;subangular t rounded; some grains coated(algal); 3 small white worms; frosting varies; poorly sorted - some bioclastic	1.55
17-2	70	30				Grey silty clay; silt-fine sand, mostly clear qtz, subangular to subrounded; much frosting; faecal pellets very abundant as are forams; diatoms present	1.37
17-3	100					Grey clay; occasional shell fragment; 1 worm tube (thin shell of silt grains);forams&diatoms abundant;faecal pellets very abundant	4.25
17-4	10		80	10		Very poorly sorted sand ranging from very coarse sand to clay; med-coarse pred.,larger grains more rounded; smaller are angular to subangular & well frosted;some rock grains; forams	1.65
17-5	15		70	15		Very poorly sorted sand; med-fine pred.; clear qtz., much brown algal coating; much bioclastic & some plant material; subangular to subrounded; rock grains abundant	0.61
17-6	80	20				Grey silty clay;some sand grains;abundant faecal pellets&forams; diatoms present;few coarse sand grains and shell fragments	3.08
17-7	?	?	?	?	some		

L. Fruth